VOLUME IX. NUMBER 4

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY

April, 1915

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

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OF CANADA

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PLATE VII.

Margaret L. Huggins.

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DEATH OF LADY HUGGINS

BY C. A. CHANT

ON March 24th, 1915, Lady Margaret Lindsay Huggins passed away in London, England, in her 67th year. Her father, John Murray, was a Dublin solicitor. She was educated at home and at a private school at Brighton.

Even in childhood she showed interest in scientific matters, especially in astronomy; and she occupied herself in studying the constellations and in observing sunspots. At this time her chief books of study were by Sir John Herschel and Dr. D. Lardner. Science certainly owes a debt to these two gifted men. Their well-written and well illustrated treatises, though of course now behind the times, can still be read with pleasure and profit. In addition, she experimentally studied elementary chemistry and physics and obtained a good knowledge of photography.

In 1875 Miss Murray married Dr. William Huggins, who had been engaged for ten years or more in laying the foundations for the science of astrophysics. Just at this time the sensitive dry-plate was introduced and Dr. Huggins began to use it in his

researches. With enthusiasm she devoted herself to her husband's work and became his sole assistant. Her special task was to guide the telescope so that the image of the star should always be upon the narrow slit of the spectroscope. For thirty-five years they labored together and the numerous papers bearing their names as joint-authors commanded the admiration of the scientific world. For his distinguished services Dr. Huggins was knighted in 1897, on the occasion of the Queen's Diamond Jubilee. At the age of 86 he passed away in 1910.

Along with her friend, Miss Agnes M. Clerke, in 1903, Lady Huggins was elected an Honorary Member of the Royal Astronomical Society. Before that date this honor had been conferred on only two women, Caroline Herschel and Mrs. Somerville. Within the last few weeks the Society has voted to admit women as ordinary members.

Lady Huggins was also deeply interested in art, music and archæology and she made considerable studies in archæological astronomy. It was natural also that she should give some attention to educational matters. In earlier life she was an earnest Sunday-school teacher, while later she served as one of the managers of a group of board schools.

In 1899 appeared "An Atlas of Representative Stellar Spectra," a volume full of scientific interest and produced in beautiful form. The initial letters and other decorations are by Lady Huggins. This constitutes volume I. of "The Publications of Sir William Huggins's Observatory." In 1909, volume II., which contains the complete "Scientific Papers" was published.

Lady Huggins was the author of a monograph on the Astrolabe and of various papers in astronomical and archæological journals. She was also the author of Lives of Agnes and Ellen Clerke, and of some other literary papers.

THE ORBIT OF 136 TAURI.

By J. B. Cannon

THE variable radial velocity of the star was discovered by Mr. Lows from the measurement of the second plate of a series of five, the results of which are published in *L. O. B.* 199. The orbit determination given below is based on 60 plates obtained here, — the first on November 16, 1911 and the last on January 15, 1915. The spectrum is of *A*-type. Two spectra are visible but so faintly on our plates that they were not considered worth measuring. On four out of the five Lick plates, however, the second component was measured and on these alone is based the secondary curve seen in the accompanying figure, — "Velocity curve of 136 Tauri."

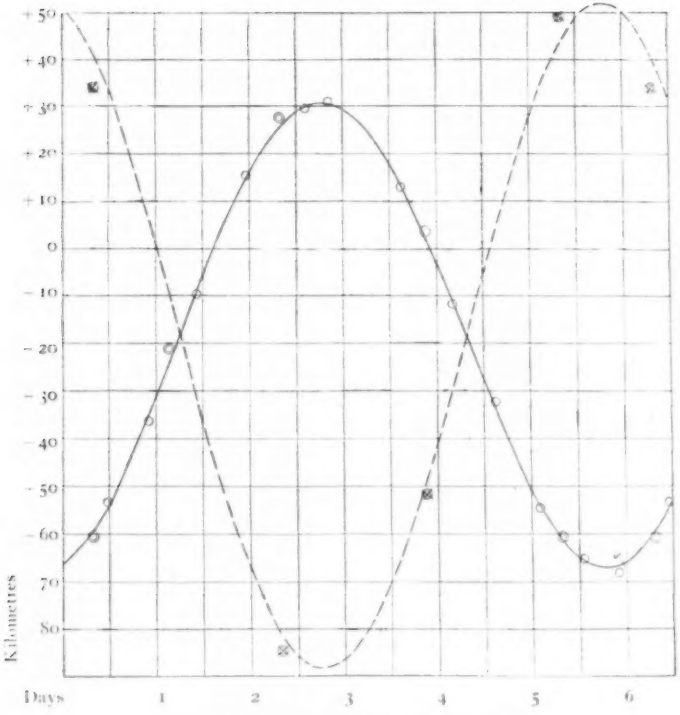
The lines measured were as follows.

TABLE I.

Element	Wave-Length
H	4861·527
Fe	4549·766
Mg	4481·400
H	4340·634
H	4101·890
H	3970·177
Ca	3968·625
Ca	3933·825

A summary of the measures is given in Tables II. and III. Table II. contains the Lick observations and Table III. the Ottawa observations. In each case the phase is from periaston and the residual from the final curve.

Measures in detail of the different plates follow Table III.



VELOCITY CURVE OF 136 TAURI

TABLE II. — LICK OBSERVATIONS

Julian Date	Phase	V_1	R_1	V_2	R_2
2,418,402·64	1·149	− 21·0	+ 2·8		
739·66	3·889	+ 3·8	+ 1·0	− 51·7	− 2·5
954·03	0·340	− 60·8	− 1·3	+ 34·0	− 7·0
950·02	5·329	− 60·6	+ 1·0	+ 49·3	+ 5·3
952·99	2·329	+ 27·8	+ 2·0	− 84·4	− 3·0

TABLE III. — OTTAWA OBSERVATIONS

Plate	Ob.	Date	Exposure	Julian Day	Phase	Velocity	Wt.	O-C
		1911	m					
4697	H	Nov. 16	75	2,419,357·820	1·269	−11·0	5	+ 7·0
4718	C	Dec. 6	65	377·807	3·347	−22·6	3	− 0·4
		1912						
4840	H	Feb. 13	70	446·589	0·508	−43·6	3	+10·4
4851	H	" 20	103	453·670	1·019	+10·0	4	+10·0
4860	C	" 28	70	461·642	3·021	+12·5	7	− 1·8
4871	H	Mar. 5	90	467·661	3·070	+10·4	5	− 1·6
4885	C	" 13	75	475·554	5·593	−60·1	2	+ 6·0
		1913						
5314	P	Jan. 12	85	780·717	0·367	−47·8	6	+10·7
5368	C	Feb. 11	70	810·580	0·390	−45·8	6	+12·2
5361	P	" 12	75	811·630	1·439	− 7·5	6	+ 1·5
5371	P	" 17	75	816·612	0·451	−47·6	4	+ 8·4
5384	H	" 18	72	817·610	1·449	− 6·1	5	+ 2·4
5393	C	" 24	75	823·640	1·509	− 6·2	5	+ 1·0
5408	P	" 28	75	827·592	5·461	−58·9	5	+ 5·0
5417	C	Mar. 7	75	834·623	0·552	−42·9	2	+ 8·7
5434	H	" 12	109	839·603	5·532	69·8	6	− 9·6
5438	P	" 17	100	844·597	4·556	29·3	2	+ 1·0
5455	C	Apr. 9	70	867·545	3·034	+14·5	3	+ 0·5
5468	P	" 14	75	872·561	2·680	+42·3	6	+11·7
5488	H	" 17	75	875·548	5·667	−59·9	4	+ 6·9
5850	C	Dec. 22	35	2,420,124·814	4·233	−10·8	5	+ 3·2
		1914						
5936	P	Feb. 14	60	178·656	4·355	−14·5	5	+ 5·5
5987	C	Mar. 20	73	212·638	2·517	+17·2	5	−12·0
6007	C	Apr. 3	75	226·525	4·474	−20·5	7	− 0·5
6014	C	" 5	73	228·540	0·519	−66·3	7	−12·8
6015	H	" 6	75	229·560	1·539	−17·2	5	−13·2
6024	C	" 10	82	233·538	5·511	−72·0	5	− 7·0
6030	H	" 13	76	236·569	2·578	+28·1	5	− 1·8
6032	C	" 14	75	237·553	3·542	+19·1	4	+ 2·1
6035	P	" 17	80	240·552	0·591	−68·0	4	−17·5
6040	P	" 22	100	245·549	5·588	−64·4	5	+ 1·6
6046	H	" 23	66	246·540	0·609	−53·6	6	− 3·8
6053	C	May 1	70	254·559	2·658	+27·1	3	− 3·2
6396	Y	Sept. 17	72	393·841	4·653	−38·5	6	− 3·5
6404	P	" 18	75	394·894	5·706	−64·0	5	+ 3·0
6420	C	" 21	75	397·894	2·727	+26·6	5	− 4·2
6431	G	" 25	75	401·911	0·775	−42·2	4	− 0·0
6436	Y	" 27	50	403·927	2·801	+34·9	6	+ 4·1
6444	C	" 28	70	404·913	3·787	+ 6·7	6	− 1·3
6454	C	" 30	15	406·890	5·764	−70·3	5	− 3·3
6461	Y	Oct. 1	45	407·875	0·780	−39·1	6	+ 2·0
6471	P	" 2	50	408·882	1·787	+15·4	5	+ 9·9
6484	H	" 4	60	410·867	3·772	+13·1	3	+ 5·1
6490	Y	" 11	55	417·929	4·788	−33·1	7	+ 8·0
6517	P	" 21	75	427·878	2·876	+34·7	6	+ 4·7

TABLE III. — OTTAWA OBSERVATIONS (*Continued*)

Plate	Ob.	Date	Exposure	Julian Day	Phase	Velocity	Wt.	O-C
		1914	m					
6538	C	Oct. 28	55	2,420,434·939	3·968	- 12·4	6	- 11·7
6548	C	Nov. 2	60	439·934	2·994	+ 26·8	5	- 2·9
6564	H	" 17	60	454·924	0·077	- 63·4	6	+ 2·8
6574	P	" 23	70	460·872	0·056	- 72·1	6	- 6·1
6594	P	Dec. 4	130	471·840	5·055	- 55·1	4	- 2.6
6600	V	" 5	60	472·806	0·052	- 71.0	4	- 5·0
6607	H	" 6	62	473·815	1·061	- 30·4	3	2·0
6633	H	" 15	66	482·939	4·216	- 10·8	4	+ 1·7
6642	P	" 16	85	483·946	5·225	- 50·8	3	+ 7·2
6653	V	" 22	40	489·625	4·933	- 57·5	3	- 9·5
6670	V	" 30	45	497·717	1·087	- 32·7	7	- 5·0
6674	V	" 31	40	498·707	2·137	+ 19·6	6	- 1·0
		1915						
6695	P	Jan. 8	85	506·794	4·195	- 8·3	5	+ 3·7
6711	H	" 12	60	510·786	2·218	+ 14·5	5	- 7·8
6715	P	" 15	95	513·862	5·194	- 53·5	2	+ 3·8

The sixty observations were grouped into twelve normal places. The normal places are given below in Table IV. together with the mean Julian Day, mean phase from periastron, mean velocity, weight and residual from final curve.

TABLE IV. — NORMAL PLACES

No.	Julian Day	Phase	Velocity	Weight	Residual
1	2,419,970·118	0·450	- 53·3	3·0	+ 1·0
2	2,420,448·018	0·029	- 36·2	1·5	- 1·0
3	2,419,808·190	1·441	- 9·5	2·0	- 0·5
4	2,420,267·281	1·966	+ 15·4	1·5	+ 0·8
5	2,420,118·162	2·607	+ 29·6	1·5	- 0·3
6	2,420,417·271	2·848	+ 31·1	2·0	+ 0·5
7	2,419,868·535	3·640	+ 13·1	2·5	- 0·5
8	2,420,343·708	4·183	- 11·4	2·0	- 0·6
9	2,420,298 792	4 630	- 32·1	2·0	+ 1·3
10	2,420,486·316	5·090	- 54·4	1·0	- 0·8
11	2,419,963·863	5·550	- 65·0	2·0	+ 0·4
12	2,420,438·266	5·918	- 68·0	2·0	- 1·4

The preliminary elements obtained from these by Dr. King's graphical method were as follows :

P = 5·969 days.
e = ·02
ω = 190°
K' = 49·5 km.
γ = − 17·5 km.
T = 2,419,362·52 J. D.

A closer approximation to the curve was attempted by applying a least squares solution. The period of oscillation was taken as fixed, being obtained by using both Lick and Ottawa observations, which being far apart, cover a great many cycles. On account of e being very small, T was also taken as fixed and e, ω, K', and γ used in the solution.

Observation equations were formed as in Table V.

TABLE V. — OBSERVATION EQUATIONS.

x	y	z	u	n	wt.
1	− ·778	− ·313	+ ·006	− 2·7	·3
1	− ·395	+ ·595	+ ·930	− 0·9	1·5
1	+ ·140	+ ·991	+ ·291	− 1·1	2
1	+ ·630	+ ·347	+ ·703	− 1·7	1·5
1	+ ·959	− ·832	+ ·210	+ 0·3	1·5
1	+ ·980	− ·995	− ·032	− 0·1	2
1	+ ·647	− ·073	− ·741	+ 1·4	2·5
1	+ ·152	+ ·863	− ·982	+ 1·4	2
1	− ·309	+ ·917	− ·953	− 0·7	2
1	− ·728	+ ·176	− ·702	+ 0·8	1
1	− ·980	− ·734	− ·277	− 1·0	2
1	− 1·013	− ·851	+ ·122	+ 0·3	2

when $x = \delta\gamma$
$y = \delta K'$
$z = K' \delta e$
and $u = K' \delta\omega$

Normal equations resulting from these Observations Equations were as follows: —

$$23\,x - 1{\cdot}713\,y - 0{\cdot}144\,z + 0{\cdot}037\,u - 9{\cdot}650 = 0$$
$$11{\cdot}711\,y + 0{\cdot}421\,z - 0{\cdot}970\,u + 9{\cdot}050 = 0$$
$$11\,700\,z - 0\,900\,u + 0{\cdot}545 = 0$$
$$11{\cdot}327\,u - 14{\cdot}621 = 0$$

Solving these gave

$$x = + \cdot 37$$
$$y = - \cdot 62$$
$$z = + \cdot 085$$
$$u = + 1 \cdot 244$$

from which

$$\delta \gamma = + \cdot 37 \text{ km.}$$
$$\delta K = - \cdot 62 \text{ km.}$$
$$\delta e = + \cdot 0017$$
$$\delta \omega = + 1^\circ \cdot 44$$

and hence, the new values of the elements, —

$$P = 5 \cdot 969 \text{ days}$$
$$e = \cdot 0217$$
$$\omega = 191^\circ \cdot 44$$
$$\gamma = - 17 \cdot 13 \text{ km.}$$
$$K = 48 \cdot 88 \text{ km.}$$
$$T = 2{,}419{,}362 \cdot 52 \text{ J. D.}$$

The value of Σpvv was reduced from 25 to 16, — a very substantial reduction. Excellent agreement between computed and observation equation residuals showed that any further solution would be useless and these elements were accepted as final.

The following table (Table VI.) contains a summary of preliminary and final values together with the probable errors of each element.

TABLE VI.

Element	Preliminary	Final	Probable Error
P	5·969 days	5·969 days	
e	·02	·0217	± ·014
ω	100°	191°·44	± 0°·88
K	49·5 km.	48·9 km.	± ·73 km.
γ	− 17·5 km.	− 17·1 km.	± ·52 km.
T	2,419,362·52 J. D.	2,419,362·52 J. D.	
$a \sin i$		4,011,000 km.	

The probable error of a single observation of average weight was found to be ± 4·6, and the probable error of a normal place ± ·95.

With the exception of K', the elements of the secondary, — which, as stated above, is entirely dependent on the four Lick observations, — were fixed by those of the primary, the only difference being that ω_2 becomes $\omega_1 + 180°$ or 11°·4.

A few trials of different values of K' gave 71 as perhaps the most satisfactory.

The relation between the masses of the two bodies is given by $M_1 : M_2 = K'_2 : K'_1 = 71:49$ or about 10:7.

In the figure the single circles indicate Ottawa observations, double circles Lick observations of primary, and circles crossed Lick observations of secondary.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
February 5th, 1915.

THE ORBIT OF ξ ANDROMEDÆ

By J. B. Cannon

FOUR measures of the velocity of this star are given in *L. O.B.* 199, the range of the four being 35 km. The spectral type is A but the lines are not so good as is usually the case with stars of this type. The note added to the list of measures in *L. O.B.* 199, says that "the lines are rather broad, possibly due to the effect of a second spectrum." This may be the cause of the broadness of the lines, although no indication of doubling has been observed here in any case. Fifty-eight plates were used in the work of determining the orbit, dating from September 1st, 1913, to February 12th, 1915. On the average, about 12 lines were measured on each plate and, generally speaking, the agreement was very fair. A list of the lines used and the element to which each is due follows in Table I.

TABLE I.

Wave Length	Element	Wave Length	Element
4571·958	Ti	4260·640	Fe
4549·721	Fe	4227·066	Fe
4534·139	Ti	4216·028	Fe
4501·814	Ti	4215·849	Fe
4415·271	Fe	4202·161	Fe
4404·062	Fe	4143·928	Fe
4395·505	Ti – V	4130·950	Si
4352·006	Cr. – Mg	4128·031	Si
4340·798	H	4101·820	H
4325·939	Fe	4077·885	Sr.
4314·945	Fe – Ti	4071·927	Fe
4294·528	Ti – Fe	4063·849	Fe
4289·857	Cr.	4045·975	Fe
4271·874	Fe	4005·422	Fe

A summary of the measures is given in Tables II. and III. Table II. contains the Lick measures. The four above men-

tioned are here and also another taken in 1911 and communicated by Dr. Campbell. Table III. contains the Ottawa observations. In these tables, the phase, is from periastron and the residual from the final curve.

TABLE II.—LICK OBSERVATIONS

Julian Day	Phase	Vel.	Residual
2,414,582·751	12·431	− 21·4	+ 1·0
2,416,820·764	11·704	− 15·7	+ 1·0
2,417,501·757	17·600	− 51·3	+ 5·1
2,418,206·893	12·044	− 18·2	+ 1·0
2,419,335·679	3·723	− 28·0	+ 6·5

TABLE III.—OTTAWA OBSERVATIONS

Plate	Ob.	Date	Exposure	Julian Day	Phase	Velocity	Wt.	Residual
		1913	m.					
5657	V	Sept. 1	68	2,420,012·782	5·606	− 19·4	7	− 1·0
5681	P¹	" 19	40	030·760	6·879	− 17·8	4	− 2·2
5689	C	" 22	80	033·853	8·972	− 6·1	4	− 0·9
5715	C	" 29	75	040·825	15·944	− 45·3	8	+ 5·7
5737	C–P¹	Oct. 3	75	044·750	2·102	− 43·3	8	+ 5·0
5754	C	" 6	75	047·783	5·143	− 27·3	4	4·8
5777	C	" 13	75	054·690	12·041	− 20·8	5	− 1·6
5856	P	Dec. 27	35	129·533	15·815	− 57·7	3	− 7·7
5860	P	" 31	50	133·552	2·066	47·1	4	+ 1·2
		1914						
5875	P¹	Jan. 5	60	138·538	7·053	− 5·8	6	+ 5·4
5882	P¹	" 12	60	145·576	14·091	− 45·9	3	− 9·1
6246	C	Aug. 3	75	348·859	4·167	− 38·2	6	− 7·2
6269	C	" 5	75	350·862	6·169	− 22·5	4	− 8·1
6302	V–C	" 24	79	369·747	7·287	− 7·3	8	+ 0·8
6315	C	" 26	90	371·809	9·349	− 7·3	3	− 1·6
6338	P¹	Sept. 4	75	380·817	0·590	− 60·4	8	5·0
6372	C	" 14	75	390·792	10·565	− 10·8	8	− 1·2
6385	G	" 16	85	392·692	12·465	19·4	6	+ 3·0
6401	C–P¹	" 18	75	394·724	14·497	− 35·3	8	+ 4·7
6411	P¹	" 20	90	396·778	16·551	− 47·4	8	+ 6.6
6417	H–C	" 21	79	397·729	17·502	− 59·0	7	− 2·5
6429	G	" 25	70	401·806	3·812	− 33·8	8	+ 0·7
6441	C	" 28	75	404·751	6·756	− 16·5	7	− 5·7
6446	G	" 30	80	406·625	8·630	− 11·3	6	− 5·1
6457	H–V	Oct. 1	55	407·726	9·731	− 1·4	4	+ 5·0
6466	C	" 2	65	408·641	10·646	− 2·3	7	+ 7·6
6478	V	" 4	64	410·583	12·588	− 23·4	8	+ 0·1
6494	C	" 12	77	418·789	3·027	− 47·5	4	− 6·7

TABLE III.—OTTAWA OBSERVATIONS.—*Continued*

Plate	Ob.	Date	Exposure	Julian Day	Phase	Velocity	Wt.	Residual
		1914	m					
6498	V	Oct. 13	70	2,420,419·653	3·891	−29·4	5	+4·1
6505	Pi	" 14	65	420·665	4·903	−32·7	5	−8·5
6507	V–H	" 20	90	426·729	10·967	−10·5	6	+1·3
6515	Pi	" 21	90	427·757	11·995	−25·5	7	−6·9
6523	V	" 22	60	428·792	13·030	−25·9	7	+1·6
6530	C	" 23	75	429·592	13·830	−38·4	8	−4·2
6544	Pi – C	Nov. 2	70	439·729	6·200	−14·5	5	−0·5
6551	C	" 4	75	441·634	8·105	−3·5	6	+2·2
6558	Pi	" 16	105	453·675	2·379	−46·4	8	−0·4
6560	V	" 17	83	454·638	3·342	−35·5	8	+3·3
6570	C	" 23	70	460·625	9·329	−4·3	7	+1·4
6581	C	" 27	75	464·636	13·340	−33·4	6	−4·1
6585	Pi	" 28	65	465·529	14·233	−38·5	6	−0·5
6590	C	Dec. 4	85	471·504	2·505	−40·9	8	+4·1
6614	C	" 11	75	478·507	9·503	−9·4	7	−3·4
6637	H	" 16	96	483·665	14·661	−40·4	8	+0·4
6647	V	" 20	70	487·536	0·705	−58·2	8	−3·2
6648	Pi	" 21	80	488·684	1·853	−52·5	7	−2·5
6649	V	" 22	60	489·469	2·638	−40·5	7	+3·5
6662	H	" 26	60	493·433	6·664	−5·5	7	+5·6
		1915						
6675	V	Jan. 3	60	501·540	14·709	−41·0	8	+0·5
6676	Pi	" 4	75	502·522	15·691	−47·6	7	+1·9
6684	V	" 5	60	503·483	16·642	−57·7	8	−2·9
6690	C	" 8	70	506·538	1·940	−43·4	6	+6·0
6724	H	" 21	45	519·460	14·862	−44·2	5	−1·3
6728	V	" 24	70	522·472	0·107	−55·0	6	+1·2
6772	H	Feb. 4	60	533·492	11·126	−6·6	5	+5·9
6775	V	" 9	60	538·490	16·124	−55·2	8	−3·2
6779	H	" 10	83	539·522	17·156	−60·1	6	−4·1
6780	C	" 12	63	541·495	1·362	−54·4	8	−1·8

The fifty-eight observations were grouped into twelve normal places. These are given in Table IV. with the mean Julian Day, mean phase, mean velocity, weight and residual from final elements.

TABLE IV.—NORMAL PLACES

No.	Julian Day	Phase	Velocity	Weight	Residual
1	2,420,190·230	5·922	− 18·5	2	− 2·7
2	359·875	6·912	− 8·4	3	+ 1·2
3	350·183	8·833	− 6·4	3	− 1·3
4	433·369	10·173	− 6·8	3	+ 1·1
5	475·258	11·039	− 8·7	1	+ 3·3
6	360·912	12·451	− 22·8	3·5	− 0·6
7	447·072	14·278	− 39·0	5·5	− 0·5
8	374·830	16·175	− 51·2	4·5	+ 1·3
9	460·083	0·158	− 58·6	4	− 2·3
10	354·066	1·836	− 48·4	3·5	+ 1·4
11	463·087	2·578	− 43·4	3	+ 1·0
12	408·999	3·767	− 34·5	3	− 0·5

Preliminary elements of the orbit were obtained by the application of Dr. King's graphical method. These were

$$P = 17{\cdot}7673 \text{ days}$$
$$e = {\cdot}05$$
$$\omega = 180°$$
$$K = 26 \text{ km.}$$
$$\gamma = -29{\cdot}70 \text{ km.}$$
$$T = 2{,}420{,}024{\cdot}881 \text{ J. D.}$$

A least squares solution was carried through to improve, if possible, the elements obtained graphically. The period, obtained by using Lick observations in connection with our own, covering an epoch of 334 cycles was considered as fixed. In the solution, T also was left out on account of the eccentricity being so small, and e, ω, K and γ used.

The following observation equations were formed :—

TABLE V.—OBSERVATION EQUATIONS

a	*b*	*c*	*d*	$-n$	wt.
1	+ ·521	+ ·333	+ ·821	+ 2·3	2
1	+ ·754	− ·306	+ ·594	− 1·7	3
1	+ ·950	− 1·000	+ ·016	+ 1·4	3
1	+ ·866	− ·683	− ·412	− 0·5	3
1	+ ·717	− ·191	− ·641	− 2·3	1
1	+ ·342	+ ·680	− ·920	+ 2·0	3·5
1	− ·285	+ ·902	− ·971	+ 1·9	5·5
1	− ·864	− ·311	− ·580	− 1·0	4·5
1	− 1·048	− ·992	+ ·062	+ 1·6	4
1	− ·806	− ·126	+ ·654	− 2·3	3·5
1	− ·595	− ·428	+ ·858	− 1·8	3
1	− ·190	+ ·973	+ ·950	− 0·1	3

From these, the following normal equations were derived:

$$39\,x - 4{\cdot}158\,y + {\cdot}243\,z - 1{\cdot}554\,u + 5{\cdot}500 = 0$$
$$19{\cdot}772\,y - 1{\cdot}303\,z - 0{\cdot}773\,u + 5{\cdot}948 = 0$$
$$18{\cdot}848\,z - 1{\cdot}843\,u + 8{\cdot}004 = 0$$
$$19{\cdot}547\,u - 20{\cdot}759 = 0$$

The solutions of the normal equations gave,—

$$x = - {\cdot}132$$
$$y = - {\cdot}312$$
$$z = - {\cdot}346$$
$$u = + 1{\cdot}006$$

from which

$$\delta\,\gamma = - {\cdot}13 \text{ km.}$$
$$\delta\,K = - {\cdot}31 \text{ km.}$$
$$\delta\,e = - {\cdot}013$$
$$\delta\,\omega = + 2^\circ{\cdot}22.$$

Hence the new values of the elements:—

$$\gamma = - 29{\cdot}83$$
$$K = 25{\cdot}69$$
$$e = {\cdot}037$$
$$\omega = 182^\circ{\cdot}22$$
$$T = 2{,}420{,}024{\cdot}881 \text{ J. D., as before.}$$

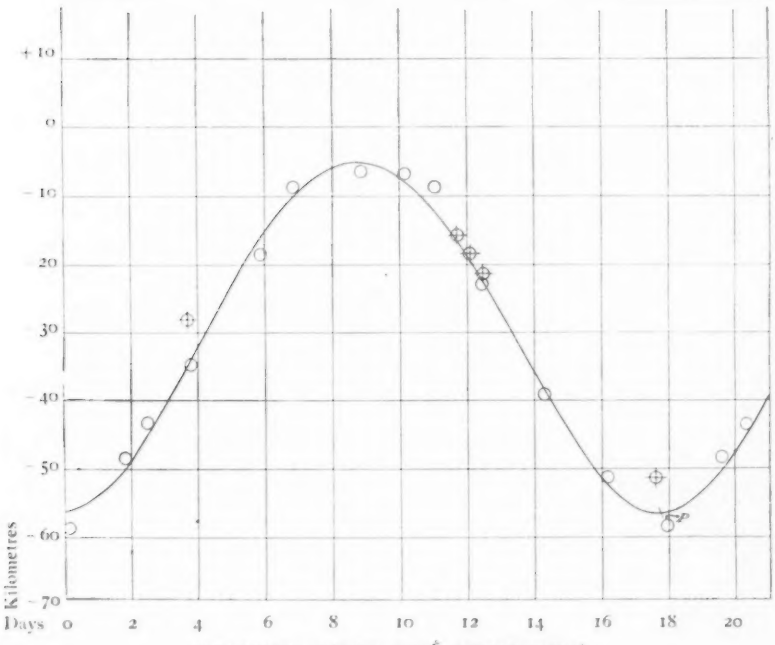
These new values of the elements gave a reduction of Σpvv from 107 to 81 or about 25 per cent. The residuals computed from the orbital elements and those from the observation equa-

tions were very nearly identical and no further corrections were attempted.

The probable error of a normal place is ± 2·1 and that of a single observation of average weight ± 2·8. The probable errors of the various elements are given after the final values in the summary following.

SUMMARY

Element	Preliminary	Final	Probable
P	17·7673 days	17·7673 days	
e	·05	·037	± ·022
ω	180°	182° 22	± 1°·27
γ	− 20·70 km.	− 29·83 km.	± 0·30 km.
K	26 km.	25·69 km.	± 0·57 km.
T	2,420,024·881 J. D.	2,420,024·881 J. D.	
$a \sin i$		6,272,000 km.	



VELOCITY CURVE OF ξ ANDROMEDÆ

In the figure the circles, are Ottawa normal places and the circles crossed are Lick observations. It will be seen that if the whole curve were raised about 3 km. the Lick observations would be better satisfied. This is probably due to different wave-lengths being used or, perhaps, to some extent to the fact that in the work here no doubt many of the lines measured are blends. Any change in the period does not seem to bring the Lick observations closer to the curve given by our own observations.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
February 25, 1915.

THE ORBITS OF THE SPECTROSCOPIC COMPONENTS OF 50 DRACONIS*

By W. E. Harper

THIS star ($\alpha = 18^h\ 49^m{\cdot}6$, $\delta = +\ 75^\circ\ 19'$, photographic magnitude 5·4) was announced as a spectroscopic binary by Frost at the Evanston meeting of the American Astronomical Society held last August. The velocities of the ten plates secured at Yerkes in June and July, 1914, were communicated by Professor Frost to the writer, who undertook the determination of the star's orbit. The period suggested was about 4·2 days.

The weather here during September and October was very favorable and 34 spectrograms were obtained before the end of the year, the majority being made in September and October. Two were rejected and the balance used in the determination. The single prism instrument, dispersion at λ 4325 being 32·1 Å. per millimetre, and Seed 27 plates were used throughout.

The spectra of both components is of the *A*-type, the intensities being nearly, though not quite, equal. Where the spectra are superposed a great many lines can be seen which are probably too faint to be recorded when the spectra are resolved. The magnesium line, λ 4481 ; the calcium, λ 3933 : H_γ and H_δ and some prominent iron lines λλ 4549, 4308, 4271, 4233, 4143, 4063, 4045, were those employed and Rowland's values for these were used.

A comparison of the Yerkes observations with our own indicated a period of 4·120 days. No attempt was made to improve this value by least squares. The plates were grouped according to phase into normal places and a least squares solution effected for the elements γ, K_1', K_2', e, ω and T. The plates where the lines were not fully resolved were combined into two groups about

* Will also appear in more detail as a Publication of this Observatory.

the crossing points, care having previously been taken to have the plates balanced in phase on either side of these points. With each of these counting as a normal place for each curve there were 20 observation equations for the solution.

Preliminary elements were obtained graphically. The eccentricity was seen to be quite small and the best that could be said of ω_1, was that it was near to 180°. Solutions were carried through for selected values of ω_1 near this value as well as a solution for $e = 0$. The results were : —

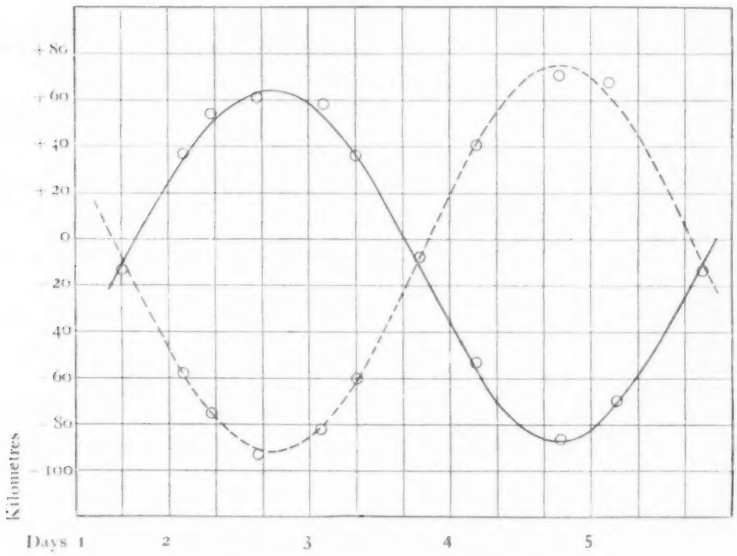
For $e = 0$	$\Sigma pvv = 271$
For $\omega_1 = 203°$	$\Sigma pvv = 230$
For $\omega_1 = 151°$	$\Sigma pvv = 226$

Thus it is seen that a small eccentricity suited better than a circular orbit and ω_1 was accepted as 151°, though the improvement over other elements with ω_1 as 203° is very slight.

The final elements, then, are :

$P =$	4·120 days
$e =$	·024 ± ·001
$K_1 =$	75·77 km. ± 1·57 km.
$K_2 =$	83·26 km. ± 1·56 km.
$\gamma =$	− 10·1 km. ± 0·8 km.
$\omega_1 =$	151° ± 0°·8
$\omega_2 =$	331° ± 0°·8
$T =$	J. D. 2,420,293·93
$A_1 =$	74·18 km.
$B_1 =$	77·36 km.
$A_2 =$	85·01 km.
$B_2 =$	81·51 km.
$a_1 \sin i =$	4,291,000 km.
$a_2 \sin i =$	4,716,000 km.
$m_1 \sin^3 i =$	0·90 x sun
$m_2 \sin^3 i =$	0·82 x sun

The graph accompanying represents the final elements and



VELOCITY CURVE OF 50 DRACONIS

the observations as grouped. The probable error of a plate is ± 3·7 km.

DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA.
February, 1915.

THE ORBIT OF THE SPECTROSCOPIC BINARY 1149 GROOMBRIDGE*

By W. E. Harper

THIS star ($\alpha = 6^h\ 18^m$, $\delta = +56^\circ\ 20'$, photographic magnitude 5·7) was announced by Adams as a spectroscopic binary from the measures† of three plates taken in the autumn of 1911. These three measures have served very materially in the accurate determination of the period.

Thirty spectrograms of the star have been secured here between February 20, 1914, and March 16, 1915, with the single prism spectrograph. The average exposure time was 78 minutes though in fair seeing 70 minutes would be ample with the dispersion employed. The star is of type *A5* and has numerous lines well adapted for measurement. From 12 to 20 are used on each plate. The probable error obtained for a plate of ± 3·7 km. per sec. is not as low as should be expected, but no plates were rejected and three or four with exposures unduly prolonged have unusually large residuals. With these omitted the probable error is reduced to ± 2·9 km. per sec.

The period was discovered from our first six or seven plates taken in conjunction with Adams' early measures and the aim was kept in view to obtain the curve with the least amount of observational data compatible with accuracy. The gaps in the curve were filled up rather slowly as cloudy weather was usually the rule at the particular phase desired. However, the observations were eventually secured and the determination of the elements is based upon these thirty plates.

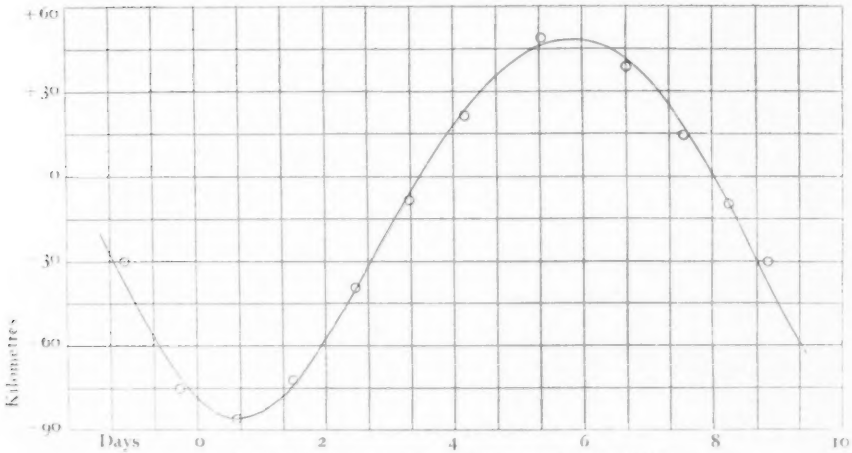
Corrections to Rowland's values of the wave lengths were obtained for this star by the customary method of equating to zero the sum of the residuals for each line velocity from the

*Will also appear in detail as a Publication of this Observatory.

†*Astrophysical Journal*, Volume XXV., page 175.

mean given by the plate. The observations were grouped according to phase, and after preliminary elements had been determined graphically a least squares solution was performed, which gave small corrections to these values and lowered the sum of the squares of the residuals about 15 per cent. The following are the final elements with their probable errors:

$$
\begin{aligned}
P &= 9{\cdot}944 \text{ days} \\
e &= {\cdot}081 \pm {\cdot}027 \\
\omega &= 152°{\cdot}9 \pm 24°{\cdot}2 \\
K &= 67{\cdot}19 \text{ km.} \pm 1{\cdot}91 \text{ km.} \\
\gamma &= -13{\cdot}74 \pm 1{\cdot}39 \text{ km.} \\
A &= 62{\cdot}35 \text{ km.} \\
B &= 72{\cdot}03 \text{ km.} \\
T &= \text{J. D. } 2{,}419{,}341{\cdot}776 \pm 0{\cdot}663 \text{ days} \\
a \sin i &= 9{,}127{,}000 \text{ km.}
\end{aligned}
$$



VELOCITY CURVE OF 1149 GROOMBRIDGE

The graph accompanying represents these elements and the observations as grouped.

DOMINION ASTRONOMICAL OBSERVATORY,
OTTAWA, CANADA,
March 22, 1915.

MAGNETIC OBSERVATIONS 1914

By Otto Klotz

DURING the season of 1914 thirty-seven stations were occupied, besides Ottawa and the base-station Agincourt, at both of which observations are always made in the spring and autumn, before and after the field work. The greater number of the stations are in a virgin field, hitherto inaccessible, being along the new Transcontinental Railway.

With the passing years we are slowly accumulating from our own observations values of annual change from a number of stations distributed over the continent, which are occupied as "repeat" stations. Beside Ottawa and Agincourt, during the past season, Quebec, Cochrane, Winnipeg and Fort William were occupied as repeat stations. As soon as we have a sufficient series of these repeat stations across the continent it is then intended to compile the magnetic elements for all our stations in Canada reduced to one epoch so that the values will be intercomparable. At present they are published annually, each for its particular time of observation, as is indicated too by the map which accompanies the official report.

The method of observing and instruments used were the same as in preceding years.

In the following two tables, a résumé of the observations is given. The first table gives the three magnetic elements observed, declination, inclination and intensity; while the other table gives the comparison at repeat stations, from which the secular change is deduced.

All the observations were made by C. A. French, of the Observatory staff.

Magnetic Results 1914

Station	Latitude	Longitude	Date	Declination	Range of Decl.	Dip	Hor. Int.	Total Int.
	° ′	° ′		° ′	′	° ′	C.G.S.	C.G.S.
Ottawa	45 23·6	75 43·0	Apr. 8 22	13 18·7W.	12·7	75 41·4	·15001	·60692
*a*Agincourt	43 47·0	79 16·0	"	6 23·5W.		74 41·4	·10088	·60930
Quebec	46 48·0	71 15·5	May 12–14	18 35·9W.	10·1	75 55·7	·14675	·60357
Hervey Jct.	46 51·4	72 28·6	" 16–18	19 18·2W.	9·0	76 36·0	·14106	·60868
Lac Chat	47 09·6	72 42·0	" 21–22	16 13·3W.	15·2	76 39·3	·14006	·60681
La Tuque	47 26·8	72 48·6	" 25–26	16 43·1W.	18·0	76 51·5	·13797	·60684
Windigo	47 46·0	73 21·5	" 27–29	18 52·4W.	13·3	76 48·5	·14012	·61400
Manuan	47 54·3	73 50·1	" 30	18 30·1W.	10·0	77 18·5	·13376	·60882
			June 1					
Parent	47 55·4	74 37·8	" 4– 5	14 59·1W.	15·0	77 34·4	·13152	·61118
Oscalaneo	48 06·4	75 10·4	" 18–19	16 10·9W.	13·9	77 56·4	·12830	·61407
White Shore Lake	48 12·0	75 40·9	" 22–23	15 26·8W.	18·4	77 42·1	·13044	·61239
Doucet	48 13·8	76 33·7	" 26–27	14 13·7W.	17·0	77 40·7	·13114	·61453
Bell River	48 23·4	77 13·9	" 29–30	13 49·0W.	12·7	77 57·2	·12895	·61785
Harricanaw	48 34·5	78 06·7	July 1– 3	12 35·3W.	15·6	78 08·5	·12707	·61837
O'Brien	48 40·2	78 41·8	" 6– 7	12 15·6W.	18·0	78 10·6	·12658	·61778
Goodwin	48 54·4	79 41·0	" 9–10	11 22·2W.	18·7	78 20·9	·12508	·61933
Low Bush	48 55·1	80 10·1	" 13–14	11 03·9W.	14·7	78 19·2	·12576	·62120
Cochrane	49 03·7	81 02·7	" 17–21	9 23·2W.	18·1	78 28·0	·12420	·62119
Fauquier	49 18·8	82 03·4	" 23	8 07·1W.	19·1	78 46·4	·12199	·62658
Mattice	49 37·1	83 16·3	" 25–27	6 49·9W.	22·0	79 00·1	·11913	·62444
Hearst	49 40·8	83 41·2	Aug. 4– 5	4 47·3W.	19·5	79 02·5	·11921	·62711
Sabinoff	49 56·8	85 01·3	" 9–10	36 42·1 E.	49·2	86 17·2	·04073	·62889
*Sabinoff			" 9				·04121	·63551
Kenogami River	50 05·1	85 49·8	" 12–13	4 21·4W.	20·3	79 14·4	·11734	·62851
*Kenogami R.			" 13				·11748	·62922
Grant	50 07·5	86 20·0	" 16–17	2 41·8W.	20·0	79 20·0	·11041	·62980
*			" 17				·11042	·62985
*b*Ombabika	50 13·0	87 56·4	" 19–20	0 49·7W.	19·9	79 25·7	·11586	·63151
*Ombabika			" 20				·11576	·63133
Armstrong	50 18·5	89 06·0	" 23–24	0 49·1 E.	19·4	79 30·2	·11398	·63402
*			" 24				·11399	·63456
Graham	50 05·5	91 54·5	" 26–28	5 15·7 E.	18·3	79 14·0	·11831	·63332
Richan	49 59·7	92 49·6	" 30–31	7 17·7 E.	17·9	78 36·7	·12612	·63872
Quibell	49 57·6	93 24·2	Sept. 2– 3	7 09·3 E.	17·3	78 55·1	·12223	·63593
Redditt	49 59·2	94 22·4	" 6– 7	9 11·0 E.	13·1	78 41·2	·12485	·63642
Malachi	49 57·5	94 58·1	" 9–11	8 29·2 E.	16·7	78 32·0	·12638	·63572
Vivian	49 53·9	96 27·5	" 13–14	11 17·2 E.	9·4	78 15·1	·12944	·63394
Winnipeg	49 51·9	97 07·9	" 16–18	13 42·9 E.	12·8	78 12·2	·12964	·63413
Emerson	49 00·2	97 12·5	" 22–23	11 05·6 E.	12·2	77 17·1	·13806	·62698
Sprague	49 02·2	95 38·3	" 25–26	9 16·3 E.	7·5	77 18·2	·13856	·63042
Rainy River	48 43·3	94 34·0	" 28–30	9 40·0 E.	9·4	77 31·0	·13590	·62871
Fort Frances	48 36·7	93 24·1	Oct. 1– 2	6 36·3 E.	12·2	77 23·3	·13747	·62961
Atikokan	48 45·3	91 38·2	" 3– 4	5 21·5 E.	10·0	77 41·9	·13382	·62809
Fort William	48 23·9	89 15·2	" 6– 7	2 57·1 E.	10·8	77 50·9	·13207	·62741
*a*Agincourt	43 47·0	79 16·0	Nov.	6 26·4W.		74 42·6	·16053	·60875
Ottawa	45 23·6	75 43·0	" 9 24	13 22·1W.	7·9	75 41·3	·14981	·60604

a—Values taken from the Journal of the Royal Astronomical Society of Canada.

b—Strong local attraction.

*—Values of Horizontal Intensity were obtained with the Dover dip circle by Lloyd's method.

ANNUAL CHANGE

Station	Date	*Obs.	Declination	Dip	Hor. Int.	Date	*Obs.	Declination	Dip	Hor. Int.	Aver. Annual Change Dec.	Dip	Hor. Int
			° ′	° ′	C.G.S.			° ′	° ′	C.G.S.	′	′	C.G.S.
Ottawa	Oct. 1906	C.I.	12 44·4W.	75 39·1	·15222	Nov. 1914	D. O.	13 22·1W.	75 41·3	·14981	- 4·7	+ ·3	- ·00030
(*a*) Agincourt	Oct. 1906	M.S.	5 47·5W.	74 36·1	·16385	Nov. 1914	M. S.	6 26·4W.	74 42·6	·16053	- 4·8	+ ·8	- ·00041
Quebec	Sept. 1906	C.I.	17 56·7W.	75 57·3	·14815	May 1914	D. O.	18 35·9W.	75 55·7	·14675	- 5·1	- ·2	- ·00018
Cochrane	July 1913	D. O.	9 16·9W.	78 29·4	·12430	July 1914	D. O.	9 23·2W.	78 28·0	·12420	- 6·3	- 1·4	- ·00010
Winnipeg	Sept. 1906	C.I.	13 59·0 E.	78 07·4	·13103	Sept. 1914	D. O.	13 42·9 E.	78 12·2	·12964	- 2·0	+ ·6	- ·00025
Fort William	June 1910	D. O	3 16·5 E.	77 49·4	·13322	Sept. 1914	D. O.	2 57·1 E.	77 50·9	13207	- 4·6	+ ·4	- ·00027

*C. I. — Carnegie Institution; D. O. — Dominion Observatory; M. S. — Meteorological Service.

(*a*) Values for Agincourt were taken from the JOURNAL OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA.

Note. — Westerly declination is considered negative (- ve), hence a negative (- ve) sign in the column "Average Annual Change of Declination" indicates that the **N** end of the needle is moving toward the west.

PLATE VIII

PHOTOGRAPH SHOWING THE STRANGE PHENOMENON KNOWN AS BLACK LIGHTNING

Original by F. C. Paisey, Weyburn, Sask.

Journal of the Royal Astronomical Society of Canada, 1915

BLACK LIGHTNING

By A. Steadworthy

THE different kinds of lightning which have been successfully recorded by photography are:— forked or zig-zag, sheet, ball, beaded, and black lightning.

The last one is so designated because it appears black instead of white on the print.

The question naturally arises,— What is the reason, what is the explanation of this anomalous phenomenon? So far as known to the writer, a satisfactory answer has yet to be given.

This phenomenon is apparently not common and hence, has received up to the present very little attention. During a long series of years photographing lightning, it was only last summer that I was fortunate in obtaining on a photographic plate, besides the ordinary lightning, a black one.

My first impression as to the cause of the black lightning was, that it was due to solarisation, which we know is the result of over-exposure. The same effect, however, may be produced by special chemical treatment of an ordinarily exposed plate. In this connection I may tell of a peculiar experience I had many years ago, and which remains a mystery to me to this day. I developed a roll of film of a dozen exposures for an amateur. In the middle were three exposures of the same object, (in Algonquin Park) made the same day under identical conditions (a bright day) and within a few minutes of each other, yet when developed, one of these three showed complete reversal, *i. e.*, the trees printed white just as we have above, the lightning printing black. One is tempted to hazard the suggestion that in the case of black lightning we are dealing with a flash of great intensity and of short wave length, to produce an effect equivalent to solarisation.

In the Annual Report of the Smithsonian Institution for 1905 is found an illustrated paper, by A. Larsen, on "Lightning," which was reproduced in the *Scientific American Supplement* for May 4th, 1907. In it is seen a plate showing both the ordinary as well as black lightning. Of the various suppositions set up for its explanation, Larsen finally falls back on the one of short wave-lengths, the wave-lengths beyond those of visibility, as already referred to.

Let us examine the accompanying Plate VIII., the original of which was obtained by Mr. F. C. Paisey, of Weyburn, Sask., and enlarged by me from a post card print. We see a fine representation of an ordinary lightning flash and a beautiful one of black lightning, the latter by far the best that has come under my notice. It will be observed that in places the paths of the two flashes cross each other. Let us do a little reasoning. We suppose we are dealing with two different phenomena, and not necessarily simultaneous. Suppose the black lightning occurs first. In this case it might occur minutes before the other, for being invisible the operator would not close his camera; this he only does when he has seen a flash. The dark lightning then acts on the plate, on the emulsion, on the bromide of silver in its peculiar way, the reverse of the ordinary flash. Then comes the ordinary flash, it is photographed, and we find its path crossing that of the black one; at such crossing we have additional light, actinic rays superposed on wave-lengths that have already had an effect equivalent to over-exposure, and hence, we are led to infer that at such crossing the over-exposure will be maintained, and consequently there will be a discontinuity in the white flash. But, as is seen on the plate, this is not the case. Let us follow the other supposition, that the black flash followed the bright one. In this case the interval of time between the two is very brief, say a second, for the operator as soon as he sees a flash closes the shutter. After the first or bright flash our plate is no longer a virgin plate, the silver bromide in the emulsion has been acted upon by the particular wave-lengths of light and has consequently undergone some chemical change.

PLATE IX.

PHOTOGRAPH SHOWING BLACK LIGHTNING

Original by A. Steadworthy, Ottawa, July, 1914.

Journal of the Royal Astronomical Society of Canada, 1915

which we assume is carried farther by the more intense black flash where it encounters the action of the bright flash.

If this assumption is correct, then again we would have a discontinuity in the print of the bright flash, but the print does not show such. We cannot get away from the fact and our attempt at explanation fails.

In Plate IX. is reproduced a photograph obtained by the writer last July at the time the spectrum of lightning was photographed, and which was published in the JOURNAL. Black lightning is also shown, the plate resembling that of Larsen.

It is scarcely necessary to say that the straight black lines shown are those of electric wires.

In writing this short note the main purpose is to draw attention to the peculiar phenomenon of black lightning; later I may have a word to say about "bead" lightning, and "faked" bead lightning.

I would suggest to those who are interested in the subject to have two cameras available during an electric storm at night; the one provided with a prism in front of the object glass, the other without the prism. The two should be so mounted that each covers the same field in the sky, which of course would mean different pointings of the optical axes of the lenses, equivalent to the refraction produced by the prism.

If a dark flash were secured by this means, we would then know from the direct image that it is black lightning and from its spectrum ascertain the wave-lengths to which the former was due. We assume, of course, that an ordinary flash will also be imprinted to serve as reference spectrum, in fact to tell us when to close the shutter.

Even if a number undertake this work, it may be some time ere the elusive phenomenon is recorded. However, even if only a small collection is obtained, we shall have something definite to go upon to unravel this interesting manifestation of atmospheric electricity.

DOMINION OBSERVATORY,
OTTAWA, CANADA.

GRAVITY STATIONS 1914

By Otto Klotz

DR. W. F. KING, Chief Astronomer, having authorized a systematic gravity survey of Canada, that work was inaugurated under my supervision during the past season, and the field-work entrusted to F. A. McDiarmid, assistant astronomer.

Under the supervision of the U. S. Coast and Geodetic Survey, a Mendenhall half-second pendulum apparatus was built for us at Washington by Saegmuller in 1902. The writer thereupon observed with it at Washington in order to standardize the pendulums and thereby be able to refer our observations to Washington as basal station, which in turn had been connected by G. R. Putnam, in 1900, with Kew, Greenwich, London, Paris and Potsdam, so that we have now a common standard for the world. Subsequently the writer observed at Ottawa in the basement of the Supreme Court building, our present Observatory not being built then. In Montreal, at McGill College, the station of Defforges was occupied, and later one at the University of Toronto.

The apparatus was taken along on the longitude campaign of completing the first astronomical girdle of the world in 1903 and 1904, when the writer observed for gravity at Suva, Fiji and at Doubtless Bay, near the northern extremity of New Zealand. The report of the gravity work done by the writer will be found in the report of the Chief Astronomer for 1905 and 1907, issued in 1906 and 1908 respectively.

From unavoidable circumstances the work could not be resumed until the past season. Mr. McDiarmid has written a full report of the operations in 1914, which will shortly be issued by the Observatory.

In this resumé of his work it may be stated, that he again

standardized the apparatus by observing at Washington, then observed here at the Observatory, again at Washington and again at Ottawa, so that the constants are well known, yet we can never abide by them indefinitely. However, as the value of gravity for Ottawa is now known and correlated to the international standard, we are able to correlate future gravity observations in Canada with Ottawa, independent of the particular period or length that a pendulum may have, for all observations are relative, and observations are made at our base station — Ottawa — before and after the field-work.

The apparatus is the same as in 1902, with the addition, however, of a U. S. C. & G. S. type of interferometer for measuring the effect of the swinging of the whole apparatus, including pier, upon the period of the pendulum; the swinging of the former being due to the swinging of the latter. The former or old method was to determine the effect statically.

Many of the stations occupied during the past season are in the vicinity of astronomic stations of former years, so that their geographical co-ordinates are accurately determined. The time of occupation of a gravity station was materially reduced by the daily exchange of clock signals with the observatory, that is, the chronometers used in the field were daily compared on a chronograph at each station with the standard Riefler clock at the Observatory, thereby avoiding carrying a field astronomic transit for making the necessary time observations, for accurate time is the pre-requisite in gravity work. It is the scale with which the period of the gravity pendulum is measured; and this period is determined in good work to an accuracy of the units in the seventh decimal of a second, that is, good observations at a station with any given pendulum should agree amongst themselves within the units of the one ten-millionth of a second of time.

Clairaut's great work "Theorie de la Figure de la Terre" was published in 1743, and in it is his celebrated theorem, which may be written in the form,

$$g_\varphi = g_0 \left\{ 1 + \left(\tfrac{5}{2} m - e \right) \sin^2 \varphi \right\}$$

in which g_φ is the force of gravity at any station at sea level, g_0 that at the equator at sea-level, m the ratio of the centrifugal force to gravity at the equator, and e the ellipticity or compression of the earth. The assumptions that Clairaut made for the above relation were*: "The strata are supposed to be ellipsoidal, and of revolution round a common axis, and nearly spherical. Each stratum is homogeneous, but there is no limitation on the law by which the density varies from stratum to stratum: the density may change discontinuously if we please. It is not assumed that the strata were originally fluid; but it is assumed that the superficial stratum has the same form as if it were fluid and in relative equilibrium when rotating with uniform angular velocity. There is no limitation on the law by which the ellipticity varies from stratum to stratum, except that the ellipticity must be continuous, and at the surface must be such as would correspond to the relative equilibrium of a film of rotating fluid." These ideal conditions do not, however, obtain upon the earth, and the reduction formula is based upon many observations taken in different and widely separated parts of the earth.

In the subjoined table the column "computed" at sea-level, the values are deduced from Helmert's formula of 1912,

$$g_\varphi = 978\,030\,(1 + \cdot005302 \sin^2\varphi - \cdot000007 \sin^2 2\varphi).$$

This formula will in time undoubtedly with the increase of data suffer slight modification, towards which our own data, hereafter accumulated, will contribute.

It will be noted that the computed g is for sea-level, while in the next column is the "observed g." This latter value is deduced from the base value of Ottawa, $g = 980{\cdot}615$, and the comparison of the periods at Ottawa and the respective station, from the relation $g : g_\varphi = t_\varphi^2 : t^2$. In order that the two values be strictly comparable the latter should be reduced to sea-

* Todhunter *History of the Theories of Attraction and the Figure of the Earth*, Vol. I, p. 221.

level. In the attempt to make this reduction difficulties and uncertainties are encountered. The only well known quantity in the reduction is the elevation of the station above sea-level, but as for the density of the mass above or below sea-level at the station little is known, or what the extent of the disturbing mass is. We have as yet in Canada no topographical sheets with contours that we can satisfactorily formulate plausible computation in such reductions, however rough estimates can be made. Mr. McDiarmid treats of this in his report.

The last column gives the elevation of the station above sea-level in metres.

We look forward with much anticipation to the results of this coming season's work, when our 600 miles "sea of mountains" along the Pacific will be entered, together with our vast western plains.

Station	Latitude	Longitude	Computed g_c	Observed g_o	$g_c - g_o$	Elevation
	° ′ ″	h m s	C.G.S.	C.G.S.	C.G.S.	m
Ottawa	45 23 39	5 02 52	980·651	980·615	+ ·036	83
Maniwaki	46 22 28	5 03 55	980·740	980·685	+ ·055	169
Kingston	44 14 37	5 05 52	980·547	980·527	+ ·020	79
Roberval	48 30 54	4 48 54	980·933	980·865	+ ·068	107
Tadoussac	48 08 25	4 38 52	980·900	980·901	− ·001	12
Portneuf	46 42 32	4 47 35	980 770	980·759	+ ·011	59
St. Jérôme	45 46 34	4 52 28	980·686	980·678	+ ·008	107
Ste. Anne de Bellevue	45 24 27	4 55 48	980·653	980·660	− ·007	31
Mattawa	46 18 43	5 14 47	980·734	980·647	+ ·087	170
Liskeard	47 30 34	5 18 50	980·843	980·785	+ ·058	194
Cochrane	49 03 44	5 24 05	980·983	980·880	+ ·103	277
Sault Ste. Marie	46 30 26	5 37 18	980·752	980·677	+ ·075	186
Chapleau	47 50 27	5 33 36	980·872	980·763	+ ·109	430
Port Arthur	48 26 00	5 56 52	980·926	980·817	+ ·109	189
Rose Point	45 19 02	5 20 10	980·644	980·602	+ ·042	183
Whitby	43 52 43	5 15 46	980·514	980·458	+ ·056	84
Woodstock	43 08 33	5 23 07	980·448	980·349	+ ·099	299
Windsor	42 19 16	5 32 10	980·373	980·338	+ ·035	178

DOMINION OBSERVATORY,
OTTAWA, CANADA

MEETINGS OF THE SOCIETY

At Hamilton

March 26th, 1915. — Professor A. A. Hibner lectured before the Local Centre this evening on "The Unsolved Problems of Astronomy."

First were described the solar system, the sun's motion among the stars and the apex of the sun's way; next the motions of the stars, their direction and amount and the question of an orbital motion of the stars. Then the question of "runaway" stars, the cause of their excessive velocity, and of whence and whither was discussed.

Is the universe limited or unlimited? Are the stars infinite in number or not? What is the source of the sun's heat? What are sun spots, the corona, the zodiacal light and the gegenschein? Does Venus rotate in a long or a short period? Is Mars habitable? All these and others were mentioned and commented upon providing a very interesting and informing evening.

Mrs. Shossenberg, Dundas, was duly elected a member.

T. H. Wingham, *Sec.*

At Winnipeg

The following meetings have been held:

January 27, 1915 — "The Spectroscope in Astronomy," Professor N. B. McLean, M.A., University of Manitoba.

February 17, — "Comets as Portents," Mr. J. H. Kolb.

February 26, — "Some Speculations Regarding Planetary

Atmospheres," Professor G. H. Ling, B.A., Ph.D., University of Saskatchewan.

The Centre understood that Dr. J. S. Plaskett would be passing through Winnipeg in March and would address our meeting, but this did not take place. Also the Centre had arranged to have an address from Mr. James Duff, M.A., President of the Regina Centre, but circumstances arose which prevented the carrying out of this plan.

On account of the lateness of the time and the approaching of the University examinations, the executive decided to hold over further meetings of the Centre until fall.

I append an outline of Dr. Ling's lecture of February 26th:

It was first thought that the atmosphere consisted of quiescent molecules resting upon one another. However, in 1845, the kinetic theory of gases was propounded, according to which the molecules of the atmosphere are moving about with a great range of velocities and colliding with one another, this motion being faster the rarer the atmosphere and therefore the fewer the collisions. A concrete notion of this state of affairs may be obtained by thinking of a room full of toy balloons which are set in violent motion by some sudden impact. The law of motion of the molecules is called the Maxwell-Boltzmann Law, and is expressed algebraically by the equation $y = 4\pi^{-\frac{1}{2}} x^2 e^{-x^2}$, where x represents the velocity of the molecule and y the number of molecules per unit volume.

From the statical theory, the atmosphere would be bounded by a smooth spheroidal surface, its depths being determined by the balancing of gravity and centrifugal force.

By astronomical researches on a large scale, Newton arrived at the conclusion that a body could be supposed to be projected from the earth at a velocity greater than a certain critical velocity, and escape entirely from the earth. According to this theory, if a molecule of gas near the outer boundary of the earth's atmosphere, where the molecules would be few in number, thus allowing few collisions, and consequently, great velocity,

were to attain a speed greater than the critical velocity, it would leave the earth never to return. In this way the earth's atmosphere would be gradually depleted. By assuming the Maxwell-Boltzmann law and an extension of atmosphere, Cook found that hydrogen and helium would escape from the earth in only very small amounts. The following table gives the temperatures at which large amounts of hydrogen, air and carbon dioxide would respectively escape from the moon and some of the planets.

	H	Air	Co_2
	°C	°C	°C
Moon	- 256	- 10	274
Mercury	209	814	1,371
Venus	205	5,033	7,403
Earth	291	9,937	14,447
Mars	- 195	1,139	1,807

Dr. Johnstone Stoney claimed that this did not hold for the moon, and that the reasoning therefore was invalidated for the planets. He assumed that helium escapes from the earth. He then found what gas would get away from the moon, say, as easily as helium does from the earth. Such a gas would escape from the moon. He further assumed that water vapor and hydrogen do not escape from the earth, and found the density which a gas would have to possess to be held by the moon, say, as readily as water vapor or hydrogen is held by the earth. In the following table some of these results are shown.

	Density Corresponding to Helium	Density Corresponding to Water Vapor
Moon	39	175
Mercury	10·25	46
Venus	2·56	11·5
Earth	2	9
Mars	9·6	43
Jupiter	0·099	0·45
Saturn	0·37	1·7
Uranus	0·74	3·4
Neptune	0·68	3·06

Dr. Stoney based his assumption on evidences that helium escapes in many instances from hot springs but is not found in the atmosphere, and does not combine with other elements, and therefore escapes from the atmosphere. This assumption is, however, now not believed with such certainty, for helium has been found to have other ways of escaping detection. The whole question is still in a very unsettled state.

It is generally agreed that the planetoids are too small to retain atmospheres.

Something may be learned as to the presence or absence of atmospheres on the heavenly bodies, from a knowledge of their reflecting powers. The presence of an atmosphere, and especially of water vapor in that atmosphere, greatly increases the reflecting power of the body. If the moon had an atmosphere it would be expected to reflect more than 13 per cent. of the light which fall upon it. Venus has a reflecting power of 76 and hence would have a dense atmosphere, which is in agreement with the observation of dense clouds on its surface. Mars reflects only 22 per cent. of the light which falls upon it, and therefore possesses probably only a small amount of moisture. According to this theory Mars may be considered as being in an advanced state of evolution, its inhabitants, if any, being at a correspondingly advanced stage and able to stand conditions of climate much more severe than ours. The earth, with its medium amount of water vapor may be considered as being in its state of prime vigor. Venus, with its excessive moisture would, according to this reasoning, be just in its youth.

H. R. KINGSTON, *Sec.*

REVIEW OF PUBLICATION

ABSTRACTS OF TWO REPORTS ON SOLAR PHYSICS

In the Annual Report of the Director of the Mount Wilson Solar Observatory,* which has recently appeared, Professor Hale enumerates 59 conclusions to which the investigations carried out at Mount Wilson in 1914 have led. Of these, 21 are devoted to Solar Physics and 10 to related laboratory investigations; the remainder, devoted to Astrophysics, have been noted in the preceding number of this JOURNAL, p. 141. The 31 results will be given verbatim as they cannot be stated more concisely:

1. Twenty-five lines, all originating at comparatively low levels in the solar atmosphere, have been found to show the existence of the sun's general magnetic field. These represent the elements, iron, chromium, vanadium, and nickel (in addition to one unidentified line), but there is every reason to suppose that other low-lying elements will also be included later.

(2) The measures show that the vertical intensity of the general field at the poles varies from a value of 55 gausses for the weakest lines (intensity 0) to 10 gausses for the strongest lines (intensity 5) yet found to show the effect.

(3) A preliminary attempt to detect the Stark effect due to electric fields in sun-spots has hitherto yielded no positive results.

(4) Accurate tests of the hydrogen lines for plane polariza-

*From the Carnegie Institution of Washington Year Book, No. 13, 1914, pp. 241-284.

tion, made under the highest dispersion with a Nicol and a compound half-wave plate, indicate that their increased width near the limb (as compared with the centre of the sun) is not primarily due to the Stark effect. Any residual influence of an electric field must be extremely small, demanding special methods of measurement for its detection.

(5) Further studies have emphasized the significance of the opposite magnetic polarity which characterizes the principal members of binary spot-groups.

(6) Before and after the recent sun-spot minimum, the preceding (or following) spots of bipolar groups have been found to be of opposite polarity in the northern and southern hemispheres.

(7) In each hemisphere the high-latitude spots of the new cycle are opposite in polarity to the low-latitude spots of the old cycle.

(8) On "flash" spectra taken without an eclipse 1,024 bright lines have been measured. These surpass in number the "flash" lines photographed in the same region at eclipses and represent a lower level in the solar atmosphere.

(9) Double reversal universally characterizes the stronger dark solar lines in these spectra.

(10) Elements of high atomic weight are found to lie below the level of iron and other lighter elements, in harmony with previous results.

(11) As there appears to be no clear evidence of systematic displacement of the bright lines, the results do not support the hypothesis of anomalous dispersion.

(12) The dark-line spectrum of these plates differs remarkably from that of the sun's centre, notably in the great weakening or strengthening of certain lines and the appearance of a few new ones.

(13) An apparent band spectrum, possibly due to magnesium hydride, has been found between $\lambda 5050$ and $\lambda 5150$.

(14) A preliminary study of the displacements of solar lines at the sun's centre gives no evidence of the existence of the gravitational shift toward the red predicted by Einstein.

(15) The results are equally opposed to Julius's anomalous dispersion theory.

(16) A discussion of the displacements indicates that in the higher levels of the solar atmosphere they are due to downward velocity of the vapors, which decreases toward lower levels and finally vanishes.

(17) Below the level of solar lines of intensity 4 or 5 the effect of pressure appears, increasing rapidly from about one atmosphere to considerably higher values at greater depths.

(18) The great mass of the vapors comprising the solar atmosphere is condensed within a very thin layer close to the photosphere.

(19) A new discussion of Mitchell's eclipse spectra yields results in complete harmony with those derived from radial displacements in spots.

(20) These "flash" spectra indicate levels for iron lines ranging from 275 kilometres for lines of intensity 00 to 806 kilometres for lines of intensity 10-40.

(21) The discussion has brought out many new facts relating to the enhanced lines in the chromosphere.

(50) 867 chromium and 1,092 vanadium lines have been classified as to their appearance and changes with temperature.

(51) The enhanced lines of the titanium furnace spectrum are not increased in intensity by the presence of a hydrogen atmosphere; on the contrary, with pressure as great as one atmosphere, the intensities are reduced.

(52) The inner vapor of a powerful condensed spark produces disymmetries of spectrum lines giving apparent displacements toward the red; the lines of the outer vapor coincide with the arc lines.

(53) Comparisons between the centre and the negative pole of the iron arc have been made for 1,600 lines. For 1,300 of these the wave-lengths are independent of the distance from the pole and the current strength.

(54) For 250 lines the wave-lengths at the negative pole exceed those at the centre by 0·015 $\mathring{A}$ or more; for 50 lines they are less at the pole.

(55) The differences vary with the current, a change from 5 to 7 amperes giving measureable shifts for lines of negative displacement.

(56) The displacements are indirectly related to pressure shifts; provisionally, they are attributed to changes in density.

(57) Because of these circumstances, the wave-lengths of the questionable lines among the tertiary standards and the international secondaries are being redetermined under standard conditions.

(58) Measures of the Zeeman separation of 769 iron, 903 chromium, and 643 vanadium lines have been made from plates taken usually with field-strengths of about 30,000 gausses.

(59) Three series of determinations of e/m give a mean value of 1·761, with an uncertainty of two units in the third decimal.

The Report discusses in detail many of the more important points summarized above; and describes the improvements in the instruments and the additions to the equipment. The 150-foot and 60-foot tower telescopes with their well-spectrographs are in perfect working order in readiness for the approaching sun-spot maximum. As the spots are already quite numerous we may look for many valuable results in the next Report. The Director promises that a report entitled "Ten Years' Work of a Mountain Observatory" will soon appear.

(Note—Many of the matters outlined above have appeared at greater length in the Contributions of the Mount Wilson Observatory and in the *Astrophysical Journal*).

In the Annual Report of the Director of the Astrophysical Observatory of the Smithsonian Institution,* Director C. G. Abbot describes the equipment, the work on the transmission of long (heat) waves through moist air, new apparatus for measuring sky radiation, and the work with balloon pyrheliometers in measuring the solar radiation at high altitudes. The results confirm the adopted value of the solar constant of radiation; and the variability of the sun has apparently been confirmed, for it seems that changes of the distribution of radiation occur over the sun's disc in correlation with the changes of the sun's total radiation.

R. E. DeLury.

* From the Smithsonian Report for the Year ending June 30, 1914.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

March, 1915

Temperature. — The mean temperature was considerably above average in the Western Provinces, and particularly so in the more northern districts, where in Saskatchewan and Alberta the positive departure exceeded 10°. From Lake Huron eastward, the departures from average were quite small, with a tendency towards being positive in the more northern parts, and negative in the south.

Precipitation and Depth of Snow on the Ground. — There was a marked deficiency of precipitation in all parts of the Dominion, except Cape Breton and apparently the North Pacific coast, and most of that which occurred was in the form of snow, except at low levels in British Columbia.

At the close of the month in the northern districts of British Columbia and on the higher levels throughout the province, there was considerable snow on the ground, while the valleys in the southern part of the province were bare the greater part of the month. The Western Provinces were quite bare of snow as were also Southern and Eastern Ontario, and the greater portion of the Maritime Provinces. In New Ontario and in Northern and Eastern Quebec, the snow was still quite deep, and in Northern New Brunswick there was a covering of several inches.

Temperature for March, 1915

Station	March		Station	March	
	Highest	Lowest		Highest	Lowest
Yukon			Kinmount	47	0
Dawson			Kingston	43	9
British Columbia			Lakefield		
Atlin			London	52	8
Agassiz	73	30	Lucknow	44	4
Barkerville	52	10	Madoc		
Kamloops	64	23	Midland		
New Westminster	70	33	North Gower	53	3
Prince Rupert	67	36	Otonabee		
Vancouver	65	33	Ottawa	45	4
Victoria	66	38	Owen Sound		
Western Provinces			Paris	73	8
Battleford	53	5	Parry Sound	47	- 1
Broadview			Peterboro'	46	2
Calgary	66	4	Port Arthur	50	- 7
Carman			Port Burwell	44	12
Edmonton	62	5	Port Dover	48	10
Medicine Hat	57	1	Port Stanley	46	13
Minnedosa	48	18	Ronville	49	- 1
Moose Jaw	54	- 1	Sarnia		
Oakbank	45	-16	Southampton	43	10
Portage la Prairie	48	10	Stonecliffe	48	- 5
Prince Albert	47	-10	Stony Creek	49	14
Qu'Appelle	50	-15	Stratford		
Regina	50	-12	Toronto	49	11
Swift Current	55	3	Uxbridge	43	5
Winnipeg	47	-15	Wallaceburg	54	10
Ontario			Welland	49	10
Agincourt	45	5	White River	45	-28
Aurora	43	6	*Quebec*		
Bancroft	49	0	Brome	42	4
Barrie			Father Point	38	4
Beatrice	45	- 7	Montreal	46	4
Birnam	45	11	Quebec	43	6
Bloomfield	47	7	Sherbrooke	47	4
Brantford	50	9	*Maritime Provinces*		
Bruce Mines			Charlottetown	46	14
Chatham	56	10	Chatham	49	4
Clinton	44	9	Dalhousie	43	8
Cottam			Fredericton	49	7
Gravenhurst	46	- 2	Halifax	54	18
Guelph	45	9	Moncton	50	8
Haliburton	49	-14	St. John	52	9
Hamilton	48	13	St. Stephen	54	9
Huntsville	48	- 3	Sussex	49	8
Kenora			Sydney	50	17
			Yarmouth	43	15

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors. L.W. = Large Waves. A.C. = Air Currents.
Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1443	Mar. 5		4 35·1	4 35·7	4 52·0	0·6	0 16·9	P not recorded.
1444	" 11	18 54·0?	19 16·3	19 22·3	19 55·0?	0·3	1 1·0	other quake.
1445	" 12	15 25·5?	15 53·9	16 10·3	16 38·0?	0·2	1 12·5	beginning of an- 15 53·9 may be the
1446	" 17		19 8·1?) 19 35·9)		A.C.	0·1		A.C. going on.
1447	" 20	22 12·6?	22 35·8		23 14·0	0·1	1 1·4	A. C. at times.
1448	" 23	21 30·0?	21 42·9	21 46·8	22 12·2	0·5	0 42·2	Gradual beginning and ending.

Period 18 seconds. Pillar inclination 1 mm. = 0″·59.

VICTORIA, B. C.

F. N. Denison, Superintendent.

No.	Date 1915	P.T. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1451	Mar. 5		4 33·6	4 35·6	4 43·1	0·5	0 09·5	
1452	" 11	18 50·7	18 58·7	19 03·7	19 13·7	0·4	0 23·0	
1453	" 12	15 14·7	15 27·7	15 29·7	15 34·7	0·1	0 20·0	Times uncertain.
1454	" 12	15 48·7	16 02·7	16 03·7	16 22·7	0·1	0 34·0	Times uncertain.
1455	" 17	19 02·4		19 11·4	19 25·4	0·2	0 23·0	[Nos. 1453 and 1454 may be one quake.
1456	" 23		21 55·0) 21 59·0)	22 00·5	22 05·0	0·2	0 10·0	Phases not defined.

Period 18 seconds. Pillar inclination 1 mm. = 0″·54

J. Y.

MAGNETIC OBSERVATIONS

During the month of March, 1915, the photographic curves of the magnetic elements, secured at Agincourt, indicate more or less disturbance except during the first four days. The most pronounced magnetic storm occurred on the 21st and 22nd. Its commencement is masked by an almost unbroken series of small movements which began on the 16th. The larger movements, however, marking the storm, began somewhat abruptly at $0^h\ 52^m$ on the 21st with increase in H of 23γ and decrease in V of 31γ. In D the beginning is not noticeable. In all three elements the general form of the curve suggests a slow oscillatory movement of the disturbing force. The most rapid change of large amplitude began at $19^h\ 20^m$ in D with decrease in westerly Declination of 47′ in 25 minutes of time and then an increase of 38′ in the next 30 minutes. In H the force decreased 46γ and then increased 95γ in corresponding time intervals, whilst in V the force first increased 21γ and then decreased 52γ.

March, 1915		D. West	H	V	I
		° ′			° ′
	Mean of Month	6 27·2	0·16039	0·58673	74 43·3
	Maximum	6 42·1	0·16085	0·58750	
	Date of Maximum	21	7	7	
	Minimum	5 48·7	0·15969	0·58588	
	Date of Minimum	21	20	20	
	Monthly Range	0 53·4	0·00116	0·00162	
Mean Daily Amplitude	From hourly readings	0 10·1	0·00031	0·00014	
	From Means of Extremes	0 19·6	0·00058	0·00035	

H and V are expressed in C. G. S. Units.

I is the Mean of all Dip observations made during the month with the Earth Inductor, without regard to the time of day at which they were made. Two observations are usually made each week.

ASTRONOMICAL NOTES

THE THEORY OF THE MOON'S MOTION. — A brief review of an address by Professor E. W. Brown before the sub-section of cosmical physics at the Australian meeting of the British Association is given in the December number of *The American Journal of Science*. In the course of the address the speaker said that the principal deviations of the moon from its calculated path "consist first of the great inequality discovered by Simon Newcomb having a period of some 270 years and amplitude of about 12 seconds of arc. This is a deviation of the moon in front of and behind its theoretical position. Superposed on this are smaller deviations which appear to have a main period of between 60 and 70 years and a coefficient of 3 or 4 seconds. But it is pointed out that this is not a periodic change in the proper sense, for it has been found impossible to analize it. It is these deviations which have formed the subject of a number of hypothesis. It appears now to be fairly certain that they cannot be accounted for by any gravitational cause.

"Professor Brown rejects many of the hypothesis which at first sight seem possible; for example, a planet inside the orbit of Mercury or a swarm of small bodies near the sun. Bottlinger's hypothesis of the shading of gravitation by interposing matter is attractive, but the curve he gets does not fit the observed deviations and according to theory it should not be able to account for them. The motion of the magnetic field of the earth have also been mentioned," but it is to be rejected because this hypothesis would require changes in other parts of the moon's orbit which cannot be admitted.

For the ellipticity of the earth Professor Brown finds in three different ways the number 1/294, which agrees with Clarke's value obtained from geodetic measures (1/293·5) but differs from Helmerts determinations (1/298), and he believes that the evidence for 1/294 is sufficiently strong to require its adoption for astronomical purposes.

He urges that at some governmental observatory in the southern hemisphere the Harvard method of obtaining the position of the moon by photography be systematically employed.

An interesting statement is made as to the degree of accuracy of the Newtonian law. From the agreement of the theoretical and observed motion of the moon's perigee it is concluded that the index which the inverse square law contains does not differ from 2 by a fraction so great as 1/400,000,000.—February Number, *Popular Astronomy*

A STANDARD TEST FOR SMALL TELESCOPES.—In *Comptes Rendus*, Tome 160, p. 18, M. G. Bigourdan describes a method of determining the separating powers of small telescope by reference to standard measurement.

The telescope is directed to a sheet of paper at a distance of 10 metres, and a group of parallel lines or bands is ruled on the paper, the breadth of the bands and of the intervals seperating them being the same.

If the ruling be such that the breadth of a pair, that is of one black line and one white interval, be one millimetre, its angular breadth in the field of the telescope will be 20″, and if the breadth of the ruling be ½ mm. or 3 mm., it will be seen as 10″ or 60″.

M. Bigourdan's paper contains a diagram showing 25 ruled spaces, each about the size of a postage stamp, numbered 10″, 12″, 14″, to 60″, and representing groups of arcs of these values. If the diagram be placed at a distance of 10 metres, the number of the space in which the ruling is just clearly visible in the telescope will be the standard measure of its separating power.

If it is preferred to adopt some distance other than 10 metres for making the test, all the angles will be increased or reduced

in the ratio which 10 metres bears to the distance chosen.—*Journal B. A. A.*, February, 1915.

THE TOTAL SOLAR ECLIPSE, 1914, AUGUST 20-21.—Extensive preparations were made for observations of the total eclipse of the sun of 1914, August 20-21, the track of which extended across Norway and Sweden, and across Russia from Riga, through Minsk and Kiev, to the Crimea. In addition to numerous Swedish and Russian astronomers, there were four British official expeditions, and parties of observers from the Argentine, France, Germany, Italy, Spain, and the United States.

The outbreak of war at the beginning of August naturally caused serious disturbance of the plans of some of the intending observers. The British expedition to Kiev had to be abandoned, and the German astronomers who had gone to the Crimea were either ordered to leave the country or detained as prisoners of war. A party from Amherst College, under Professor Todd, succeeded in reaching Kiev but were unable to get their instruments forwarded. Mr. R. C. Slater, who had sent his instruments to Riga in advance, was obliged to change his plans, and made his observations with improvised apparatus at Stromsund, in Sweden. The Rev. C. D. P. Davies and others who had intended going to Russia were unable to commence the journey, although in some cases instruments had already been dispatched.

Notwithstanding the distracting conditions under which the preparations had to be carried on, it is gratifying to record that interesting results were obtained by most of the observers who were fortunate enough to witness the eclipse in clear skies.

The expectation from meteorological records was that the most favourable localities would be in South Russia, but the actual conditions were almost completely the reverse. In Sweden the eclipse was seen under exceptionally good conditions, and at Riga also the sky was very clear. Further south, near Minsk, observations were only possible for the Greenwich party because of a fortunate gap in a cloudy sky. In the neighbour-

hood of Kiev it was too cloudy for observations, while in the Crimea the sky was generally cloudy, but with gaps which permitted observations at some of the places occupied. It is greatly to be regretted that among those who failed to secure observations were Professor Campbell's party from the Lick Observatory, which was stationed near Kiev, and Professor Newall's party from the Solar Physics Observatory, Cambridge, which occupied a site a few miles outside Theodosia, in the Crimea.

Successful photographs of the corona were obtained by, among others, Father Cortie at Hernösand, Mr. Slater at Strömsund, Dr. Backlund at Riga, and by Messrs. Jones and Davidson near Minsk. The corona is described generally as being of the expected "intermediate" type, in accordance with the phase of the sun-spot period, which was on the rise from minimum to maximum.

Records of the flash spectrum do not appear to have been very numerous. There is promise of an important advance in our knowledge of the ultra-violet part of this spectrum, however, through the photographs taken by Messrs. Jones and Davidson with the Hills 4-prism quartz spectrograph, which show numerous lines extending as far as λ3100. Also, some good plates of the red region of the spectrum were obtained by the Madrid astronomers, Messrs Carrasco and Ascarza, who were stationed at Theodosia.

The most striking feature of the eclipse results yet reported was the unusual character of the spectrum of the corona. The familiar green line, λ5303, is stated to have been absent, or extremely faint, while a previously unrecorded red line was very prominent. The wave-length of the latter is given as 6374·5 by Messrs. Bosler and Block, who formed the expedition from Meudon to Strömsund; and as 6373·87 by Carrasco and Ascarza. The substance represented by the new line, as in the case of the green line, has not yet been identified. Other well-known coronal lines besides that in the green were also missing.

Father Cortie reports several faint *groups* of lines in the coronal spectrum, two of which include the red and green lines at 6374 and 5303; he considers that these groups may possibly represent a band spectrum.—*Monthly Notices R.A.S.*, February, 1915. J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERIES

Referring to Mr. Stupart's Lecture [on "Solar Radiation and Weather Types", in Toronto, March 9.]

1. Have photometric measurements [of the sun] been made along with the heat measurements referred to in the lecture?

2. If sun-spots result in increased heat radiation, should not the luminosity vary in universe proportion to the heat radiation?

3. Are the variations of heat and light in our sun sufficient to entitle it to be called a variable star? Or, in other words, would such variations be visible or measurable at astronomical distances?

Regarding Interstellar Space.

4. Are we justified in supposing that all matter has been by condensation removed from interstellar space? Seeing that matter originally must have been conterminous with space; also seeing that finely divided matter is continually falling in on the sun and planets; it seems to me that the total abstraction of matter from interstellar space would mean the "death of the universe," an event which is probably still countless æons removed from the present time.—S. DILLON MILLS, (Toronto).

ANSWERS

The above queries were submitted to Director Stupart, and at his request Mr. J. Patterson, M.A., Physicist to the Meteorological Service, answers them as follows:

1. As far as I know, photometric measurements have not been made.

Luminosity is simply the effect of certain radiations on the eye and cannot be defined in absolute units, so that I do not see that photometric measurements of the sun would have any

special value. Those radiations that give luminosity are only a small portion of the radiations that give heat and are all included in the latter.

2. I suppose the inference here is that the sun-spots cut off a certain amount of light and that the luminosity of the sun will be diminished by that. This implies that, apart from the sun-spots, the luminosity is constant; but if sun-spots result in increased heat radiation it means that there is increased activity in the sun and more energy is being given out. This would lead one to expect increased luminosity. By far the greater part of the heat radiation given out by the sun comes from the infra red and red parts of the spectrum and there is thus not a simple relation between luminosity and heat radiation, and I do not think that one can draw any definite conclusion from the variation of heat radiation due to sun-spots as to how the luminosity would vary.

3. That depends on the magnitude of the variation you require in the heat or light from the sun before you would call it a variable star. Heat variations amounting to about 15 per cent. have been measured by Dr. Abbot, and as mentioned in (1) the heat measurements include a very much greater range of radiation than the usual radiation. In the stars it is not possible to measure the heat radiation from them and one has to depend on the light for a measure of their constancy. Dr. Abbot thinks we can properly consider the sun to be a variable star.

4. We know that there are countless numbers of meteoroids in space and there may be matter in all states of division that gets beyond the influence of one planet and is being drawn into another, but the amount of very finely divided matter in interstellar space must be so small that it does not absorb any appreciable amount of radiation from the sun. Our own atmosphere absorbs about a third of the radiation coming from the sun, and you can imagine how much matter there could be in the remainder of the distance to the sun if there were no appreciable amount of radiation absorbed in its passage through.

WHEN ICE FORMS AND BREAKS UP ON THE MACKENZIE RIVER

In his paper on "A Meteorological Trip to the Arctic Circle" in last month's issue, Mr. J. Patterson gave much interesting information regarding the meteorological conditions of the Mackenzie River basin. He reports that he has just received from Father Ducot, O.M.I., of Fort Norman, the following table giving the dates, from 1883 to 1914, on which the ice formed in November and on which it broke up in May.

Year	Date of Freezing in November	Date of Breaking up in May	Year	Date of Freezing in November	Date of Breaking up in May
1883		12	1899	13	
1884			1900	11	12
1885		10 to 20	1901	9	23
1886		23	1902	13	20
1887	7	24	1903		26
1888	11		1904		
1889	22	25	1905		
1890	13	10	1906		
1891	7	25	1907	11	
1892	before 18		1908	3	20
1893	8	18	1909	13	21
1894			1910*	14	21
1895	11		1911	15	14
1896	18	18	1912	11	19
1897	5	21	1913	18	20
1898		15	1914	16	14

* On the 6th May, 1910, there was a very heavy fall of rain, which was most extraordinary at that time of the year.

SOUNDS ACCOMPANYING AURORÆ?

(Communication)

With regard to the mention of this question in the "Notes and Queries" columns of the JOURNAL, I would like to remark that the point is an interesting one though I believe the great weight of evidence is of a negative character.

Sounds have frequently been alleged to come simultaneously with the flights of meteors, but these experiences are on a par with the supposed noises attending auroræ. They are either

imaginative or due to causes not directly associated with the phenomena observed. Auroræ and meteors are usually at great distances from the observers and it can hardly be admitted that they are capable of producing noises which are instantaneously transmitted. It will be remembered that the velocity of sound in ordinary air is about 12½ miles per minute, whereas noises have been said to have come at the same moment as the visible combustion and explosion of meteors 100 miles or more distant.

This is impossible unless the acoustics of meteoric detonations require a vast different explanation to that usually applied. As to auroræ, I have witnessed a large number of fine exhibitions during the last fifty years but, though blessed with good hearing powers, have never recognized any audible noises proceeding from them. The great changes and transformations affecting certain auroral displays, at short intervals, have taken place all silently. I am, therefore, disposed to think that ordinary auroræ, like the generality of meteors, are noiseless, but there may just possibly be a special form of aurora which, similarly to the ærolite as it falls to the earth, produces sounds of a distinctly audible nature. Such incidents may, however, be very exceptional and as rare as ærolitic visitations.

W. F. Denning.

Bristol, England,
March 22, 1915.

VELOCITIES OF THE NEBULÆ—MORE HIGH VALUES

Some of the remarkably high radial velocities of nebulæ and stars, as obtained at the Lowell and Lick Observatories, were given in last month's issue. More are now available from the Lick Observatory's southern station in Chile. Dr. Ralph E. Wilson is at present in charge of that station and in the *Proceedings* of the National Academy of Sciences, Vol. 1, No. 3, he gives the radial velocities of five nebulæ in the bright southern areas of the sky known as the Magellanic Clouds. The following account of this work is from *Popular Astronomy* for April:—

"These five nebulæ are all receding from the sun with remarkably high velocities, one in the Lesser Cloud having a radial velocity of 158 kilometres per second as measured on three spectrograms, and four in the Greater Cloud having an average of 275 kilometres. All these nebulæ have bright-line spectra, and three lines, $H\beta$ (hydrogen), 5007 *A* (nebulium) and 4959 *A* (nebulium), were measured in each case. The spectrograms were taken with a spectrograph especially designed for work on the nebulæ, attached to the 37-inch reflecting telescope of the D. O. Mills Expedition from the Lick Observatory, at Cerro San Cristobal, Santiago, Chile.

'It is difficult to doubt that these nebulæ are actually within the structure of the two Clouds, respectively: N.G.C., 1644, seen upon the Smaller Magellanic Cloud as a background, is the only known bright-line nebula in that region of the sky; and the others are four of the nineteen known bright-line nebulæ closely clustered upon the background of the Greater Magellanic Cloud, which are almost equally isolated from other nebulæ of their kind'

From private letters recently received we learn that others of the nebulæ in the greater Cloud yield the same average high velocity with the first four, and it would seem that possibly the entire Cloud is receding from us with astonishing speed."

Dr. Ralph Wilson is a son of Professor Herbert C. Wilson, Editor of *Popular Astronomy*.

SILVERING OF MIRRORS AND PRISMS

The Editor has received a letter from Messrs. Laing, Wharton, Limited, Manufacturing Electrical Engineers, Mildmay Avenue, London N., England, regarding the silvering and resilvering of astronomical mirrors, flats, prisms, etc. This firm is desirous of obtaining business in this line in Canada and the present is surely the time for the various parts of the Empire to stand together.

Messrs. Laing, Wharton have been in business for eighteen

years, and from the complimentary statements made by Cambridge University and other educational bodies, I have no hesitation in commending their work. They use the nitrate of silver process and in connection with prisms, glasses, etc., silvered on the back, they provide electro-deposited copper backing for mechanical protection and acid-proof paint to the backing, so that these surfaces practically stand indefinitely.

Canadian astronomers, I am sure, would make no mistake in patronising this British firm.

C. A. C.